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TRANSMITTAL FORM

(to be used for all correspondence after initial filing)

Application Number	09/996,423
Filing Date	November 28, 2001
First Named Inventor	Whitman et al.
Group Art Unit	2823
Examiner Name	T. Pham
Attorney Docket Number	2269-4294.3US

ENCLOSURES *(check all that apply)*

- [x] Postcard receipt acknowledgment (attached to the front of this transmittal)
- [x] Duplicate copy of this transmittal sheet in the event that additional filing fees are required under 37 C.F.R. § 1.16
- [ ] Preliminary Amendment
- [ ] Response to Restriction Requirement/Election of Species Requirement dated
- [ ] Amendment in response to office action dated
- [ ] Amendment under 37 C.F.R. § 1.116 in response to final office action dated
- [ ] Additional claims fee - Check No. in the amount of $
- [ ] Letter to Chief Draftsman and copy of FIGS. with changes made in red
- [ ] Transmittal of Formal Drawings
- [ ] Formal Drawings (sheets)
- [ ] Information Disclosure Statement, PTO/SB/08A; [ ] copy of cited references
- [ ] Supplemental Information Disclosure Statement; PTO/SB/08A; copy of cited references and Check No. in the amount of $180.00
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  APPEAL BRIEF (IN TRIPLICATE); and Check No. 6512 in the amount of $330.00.

Remarks

The Commissioner is authorized to charge any additional fees required but not submitted with any document or request requiring fee payment under 37 C.F.R. §§ 1.16 and 1.17 to Deposit Account 20-1469 during pendency of this application.

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT

Firm or Individual name	Brick G. Power	Registration No. 38,581
Signature	Brick G. Power	
Date	August 18, 2004	

CERTIFICATE OF MAILING

Express Mail Label Number: EV348043365US

Date of Deposit: August 18, 2004

Person Making Deposit: Christopher Haughton

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:

Whitman et al.

Serial No.: 09/996,423

Filed: November 28, 2001

For: SPIN COATING FOR MAXIMUM FILL CHARACTERISTIC YIELDING A PLANARIZED THIN FILM SURFACE

Confirmation No.: 2810

Examiner: T. Pham

Group Art Unit: 2823

Attorney Docket No.: 2269-4294.3US

NOTICE OF EXPRESS MAILING

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APPEAL BRIEF

Mail Stop Appeal Brief – Patents
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Attn: Board of Patent Appeals and Interferences

Sirs:

This Appeal Brief is being submitted in triplicate and in the format of 37 C.F.R. § 1.192(c). A check in the amount of $330.00 for the fee under 37 C.F.R § 1.17(c) for filing a brief in support of an appeal is enclosed.

(1) REAL PARTY IN INTEREST

The real party in interest in the above-referenced appeal is Micron Technology, Inc., the assignee of the above-referenced application as recorded with the United States Patent and Trademark Office on April 4, 2000, Reel 010729, Frame 0057.

(2) RELATED APPEALS AND INTERFERENCES

The Examiner's rejections in the parent of the above-referenced application, U.S. Patent application serial no. 09/542,783, filed April 4, 2000 (hereinafter "the '783 Application"), are currently the subject of an appeal, as are the Examiner's rejections in a related application, U.S. Patent application serial no. 09/997,019, filed November 28, 2001.

(3) STATUS OF THE CLAIMS

Claims 1-4, 7-11, 14-16, and 20-32 are currently pending and under consideration in the above-referenced application.

Each of claims 1-4, 7-11, 14-16, and 20-32 has been considered and stands rejected.

The rejections of claims 1-4, 7-11, 14-16, and 20-32 are being appealed.

(4) STATUS OF AMENDMENTS

The above-referenced application, U.S. Patent application serial no. 09/996,423 (hereinafter "the '423 Application"), was filed on November 28, 2001, as a continuation of the '783 Application. The '423 Application was originally filed with 20 claims.

A Preliminary Amendment was mailed on March 21, 2002, to correct grammatical and formal errors in the claims.

A first Office Action on the merits was mailed by the Office on November 1, 2002. Each of claims 1-20 was rejected.

An Amendment, in response to the first Office Action, was submitted on February 3, 2003, and received a filing date of February 7, 2003. In that Amendment, claims 5, 6, 12, 13, and 17-19 were canceled without prejudice or disclaimer. Several claim amendments were also presented. In addition, new claims 21-32 were introduced.

On April 15, 2003, a Final Office Action followed. Claims 1-4, 7-11, 14-16, and 20-32 were all rejected.

In a Response to Final Office Action, which was mailed on June 16, 2003, and received a filing date of June 19, 2003, several explanations as to the patentability of the subject matter recited in claims 1-4, 7-11, 14-16, and 20-32 were provided.

The Examiner was not persuaded by the explanations that had been provided in the Response of June 19, 2003, as evidenced by the remarks that accompanied the subsequently entered Advisory Action, which was mailed on July 17, 2003.

On July 22, 2003, a Request for Continued Examination (RCE) was filed, along with a petition and fee for a one-month extension of time.

Another Office Action, in which each of claims 1-4, 7-11, 14-16, and 20-32 was again rejected, followed the RCE on October 21, 2003.

Further claim revisions and explanations were presented in an Amendment dated January 21, 2004, which received a filing date of January 26, 2004. The claim revisions that were presented in the Amendment of January 26, 2004, were the last amendments submitted in the above-referenced application.

Another Final Office Action was mailed on March 19, 2004. In the Final Office Action, the Office maintained all of its rejections of claims 1-4, 7-11, 14-16, and 20-32.

A final attempt was made to convince the Examiner of the patentability of the subject matter recited in claims1-4, 7-11, 14-16, and 20-32 in a Response to Final Office Action dated May 19, 2004.

In an Advisory Action dated June 9, 2004, the Office maintained its claim rejections. In addition, the Examiner inappropriately accused the undersigned of falsifying data.

On June 18, 2004, a Notice of Appeal was filed, and is followed by this Appeal Brief.

(5) SUMMARY OF THE INVENTION

The claims that have been considered in the above-referenced application are drawn to spin coating methods for applying materials to substrates.

The inventive spin coating methods include applying a material to a substrate, spinning the substrate at a substantially constant first speed, decreasing a rate of spinning to a substantially constant second speed, and gradually increasing a rate of the spinning to a substantially constant third speed. *See, e.g.,* paragraphs **[0012]**, **[0014]**, **[0019]**, **[0040]**, and **[0041]**, In such spin

coating methods, a substrate may additionally be re-decreased to a fourth speed and re-increased to a fifth speed. *See, e.g., id.*

At the first speed, material may substantially fill recesses that are formed in the substrate. *Id.* The material may be permitted to set at the second speed. *Id.* When the substrate is spun at the third speed, the material may be spread over a surface of the substrate, forming a layer of desired thickness thereon. *Id.* A fourth rotational speed may be used to facilitate further setting of the material. *Id.* Solvent may be removed from the material by rotating the substrate at the fifth speed. *Id.*

(6) ISSUES

(A) Whether claims 1, 7, and 14 recite subject matter which complies with the definiteness requirement of 35 U.S.C. § 112, second paragraph;

(B) Whether claims 1-4 are allowable under 35 U.S.C. § 102(a) for reciting subject matter which is not anticipated by the description of U.S. Patent 6,117,486 to Yoshihara (hereinafter "Yoshihara"); and

(C) Whether, under 35 U.S.C. § 103(a), claims 1-4, 7-11, 14-16, and 20-32 are allowable for being directed to subject matter which is patentable over the teachings of U.S. Patent 5,405,813 to Rodrigues (hereinafter "Rodrigues").

(7) GROUPING OF CLAIMS

Group 1 – Claims 1, 7, and 14:

For purposes of the 35 U.S.C. § 112, second paragraph, rejections of claims 1, 7, and 14, each of these claims should be grouped together. Claim 1 is the most generic claim of this group. Insofar as the 35 U.S.C. § 112, second paragraph, rejection is concerned, claims 7 and 14 stand and fall with claim 1.

Group 2 – Claims 1-4:

For purposes of the 35 U.S.C. § 102(b) rejection of claims 1-4, each of these claims should be grouped together. Claim 1 is the most generic claim of this group. Claims 2-4 stand with claim 1 but, for the reasons that are set forth in the ARGUMENT section of this Appeal Brief, claims 2 and 3 do not fall with claim 1.

Group 3 – Claims 1-4 and 21-24:

With respect to the 35 U.S.C. § 103(a) rejection, claims 1-4 and 21-24 should be grouped together. Claim 1 is the most generic claim of this group. Claims 2-4 and 21-24 stand with claim 1 but, for the reasons that are set forth in the ARGUMENT section of this Appeal Brief, none of claims 2, 3, 21, or 23 falls with claim 1.

Group 4 – Claims 7-11 and 25-28:

Also regarding the 35 U.S.C. § 103(a) claim rejections, claims 7-11 and 25-28 should be grouped together. Claim 7 is the most generic claim of this group. Claims 8-11 and 25-28 stand

with claim 7 but, for reasons that are provided in the ARGUMENT section of this Appeal Brief, none of claims 9, 10, 25, or 27 falls with claim 7.

The claims of Group 4 should not be grouped with the claims of Group 3 since the reasons that independent claim 7 is patentable over the teachings of Rodrigues differ from the reasons that independent claim 1 is patentable over the teachings of Rodrigues. Specifically, independent claim 7 recites that material may flow into recesses of a substrate when the substrate is rotated at a first speed. This subject matter is not recited in independent claim 1 and is not rendered obvious by the teachings of Rodriques, as is explained in further detail in the ARGUMENT section of this Appeal Brief.

Group 5 – Claims 14-16, 20, and 29-32:

With further respect to the 35 U.S.C. § 103(a) rejections, Claims 14-16, 20, and 29-32 should be grouped together. Claim 14 is the most generic claim of this group. Each of claims 15, 16, 20, and 19-32 stands with claim 14. None of claims 15, 16, 29, or 31 falls with claim 14, however, for the reasons that are provided in the ARGUMENT section of this Appeal Brief.

The claims of Group 5 should be grouped separately from the claims of Groups 3 and 4 since claim 14 recites subject matter which is patentable over the teachings of Rodrigues for different reasons than the claims of Groups 3 and 4 are patentable over Rodrigues. In particular, claim 14 recites that a substrate is spun at a first speed to at least partially spread material, subject matter which is neither recited in claim 1 or claim 7, nor rendered obvious by the teachings of Rodrigues.

(8) ARGUMENT

(A) Rejections Under 35 U.S.C. § 112, Second Paragraph

Claims 1, 7, and 14 stand rejected under 35 U.S.C. § 112, second paragraph, for reciting subject matter which is purportedly indefinite. Specifically, each of these claims has been rejected for reciting the term "gradually," as it applies to the acceleration of the rate at which a substrate is spun during spin coating processes.

(1) RELEVANT LAW

With respect to determining whether relative terms, such as "gradually" are definite, M.P.E.P. § 2173.05(b) provides the following instructions:

> When a term of degree is presented in a claim, first a determination is made as to whether the specification provides some standard for measuring that degree. If it does not, a determination is made as to whether one of ordinary skill in the art, in view of the prior art and the status of the art, would be nevertheless reasonably apprised of the scope of the invention.

(2) ANALYSIS

It is respectfully submitted that the specification of the above-referenced application and the knowledge that was generally available in the art before the priority date for the above-referenced application provide sufficient guidance as to the meaning of the term "gradually," as used in claims 1, 7, and 14, that one of ordinary skill in the art would readily understand the meaning of the term "gradually," as used in claims 1, 7, and 14.

As noted in the Final Office Action, the specification of the above-referenced application, at paragraph **[0041]**, provides exemplary durations for each spinning speed set forth therein. Specifically, paragraph **[0041]** notes that the rate at which a substrate is spun may be decreased from a first speed of about 1,000 rpm to a second speed of about 100 rpm over a period of about five seconds to about ten seconds. Stated another way, the gradual decrease in the rate of spinning may occur at a rate within the range of about 90 rpm/sec (900 rpm decrease over ten seconds) to about 180 rpm/sec (900 rpm decrease over five seconds). When compared to the rotational speeds and nearly instantaneous changes in rotational speed that are described in the prior art (*see, e.g.,* U.S. Patent 6,117,486 to Yoshihara (hereinafter "Yoshihara"), this example provides one of skill in the art with clear guidance as to what is meant by the term "gradually," as that term is used in claims 1, 7, and 14.

Although the Examiner has concluded that the specification of the above-referenced application does not provide some standard for measuring the degree of the relative term "gradually," when used to describe rates at which spinning of a substrate is increased or decreased, the Examiner has not fully considered whether or not one of ordinary skill in the art would have nevertheless been reasonably apprised of the scope of the invention.

As for the understanding of one of ordinary skill in the art, the third edition of the American Heritage College Dictionary defines the term "gradual" as "[a]dvancing or progressing by regular or continuous degrees." In view of this definition, it is respectfully submitted that the term "gradually" is a relative term, which is acceptable if one of ordinary skill in the art would readily understand its meaning in light of the specification. *See* M.P.E.P. § 2173.05(b).

Turning now to references in the appropriate art, use of the term "gradual" in claims 1, 7, and 14 becomes even clearer.

Conventionally, the acceleration and deceleration of wafers during spin coating processes have been performed "as quickly as is practical to the final spin speed. Wolf, Stanley, Silicon Processing for the VLSI Era, Volume 1: Process Technology, page 431 (1984) (hereinafter "Wolf"), a copy of which is enclosed as Appendix A for the sake of convenience. This is because "[h]igh ramping rates have been shown to yield better film uniformities than low ramping rates." *Id.* U.S. Patent 6,117,486 to Yoshihara (hereinafter "Yoshihara"), on which the Office relies for several of the claim rejections that have been presented in the above-referenced application, notes that in conventional spin coating processes, rotational acceleration and deceleration may be effected at a rate of about 10,000 rpm/sec. Col. 10, lines 16-52. Yoshihara also instructs that, in the processes described therein, even quicker deceleration (*e.g.,* at about 30,000 rpm/sec) may be desirable. Col. 12, line 54, to col. 13, line 15; col. 14, lines 28-42. Wolf similarly teaches, "[a] spin-ramp of 20,000 rpm/sec has been suggested as an adequate compromise to provide maximum coating uniformity" for older, less resist-conservative spin coating methods. Wolf, page 431. Wafers are accelerated and decelerated as quickly as practical to form material (*e.g.,* photoresist) layers before solvent can evaporate therefrom.

By way of contrast to accelerating or decelerating spinning of a substrate "as quickly as practical," another reference, U.S. Patent 6,251,487 to Yonaha (hereinafter "Yonaha"), provides a nonlimiting example of "gradual" acceleration or deceleration. Based on the Yonaha, at col. 7, lines 53-64, indicates that an increase of 4,670 rpm (from 1,000 rpm to 5,670 rpm) in the spin rate of a substrate may be effected over a period of two seconds, amounting to an acceleration

of 2,335 rpm/sec. Notably, such gradual acceleration is only mentioned by Yonaha in reference to the change between an initial spin speed and an immediately subsequent spin speed. All of the other changes in the rate at which the substrate is rotated lack any reference to a rate of acceleration or deceleration and, thus, must be assumed to be about "as quickly as practical." A copy of Yonaha has already been provided to the Office.

In view of the foregoing, it is evident that "as quickly as practical" includes nearly instantaneous rates of acceleration and deceleration (*e.g.,* 10,000 rpm/sec, 20,000 rpm/sec, 30,000 rpm/sec), while "gradual" rates of acceleration (*e.g.,* 2,335 rpm/sec) are not "as quickly as practical" and consume time that has been conventionally perceived as crucial to forming a uniform film prior to evaporation of solvent from the photoresist.

It is, therefore, respectfully submitted that the meaning of the term "gradual," as it applies to acceleration or deceleration of the rate at which a substrate is rotated, or spun, would be readily apparent to one of ordinary skill in the art of spin coating. Accordingly, it is respectfully submitted that each of claims 1, 7, and 14 complies with the requirements of the second paragraph of 35 U.S.C. § 112 and, thus, that each of these claims is in condition for allowance.

Accordingly, reversal of the 35 U.S.C. § 112, second paragraph, rejections of claims 1, 7, and 14 is respectfully requested.

(B) <u>REJECTIONS UNDER 35 U.S.C. § 102(a)</u>

Claims 1-4 stand rejected under 35 U.S.C. § 102(b) as being anticipated by Yoshihara.

(1) RELEVANT LAW

A claim is anticipated only if each and every element as set forth in the claim is found, either expressly or inherently described, in a single reference which qualifies as prior art under 35 U.S.C. § 102. *Verdegaal Brothers v. Union Oil Co. of California*, 2 USPQ2d 1051, 1053 (Fed. Cir. 1987). Furthermore, the identical invention must be shown in as complete detail as is contained in the claim. *Richardson v. Suzuki Motor Co.*, 9 USPQ2d 1913, 1920 (Fed. Cir. 1989). Additionally, the elements must be arranged as required by the claim, but identity of the terminology is not required. *In re Bond*, 15 USPQ2d 1566 (Fed. Cir. 1990).

(2) REFERENCE RELIED UPON

Yoshihara describes a resist coating method. Resist is applied to a substrate as the substrate is being rotated. The rate at which the substrate is rotated is then decreased for a predetermined period of time. Thereafter, the rate at which the substrate is rotated is again increased. Yoshihara teaches that by spinning a semiconductor wafer at high speeds, lowering the speed for a time, and re-increasing its rotational speed, the wafer can be coated with material in such a way that circular ripples do not appear thereon.

As indicated in the tables of columns 9 and 10 of Yoshihara, the acceleration and deceleration between different spinning speeds are affected nearly instantaneously—at least 10,000 rpm/sec. For example, when the rate of spinning is decreased from 4,500 rpm to 2,000 rpm, at a deceleration of 30,000 rpm/sec, as disclosed at col. 9, lines 55-62, and col. 10, lines 8-10 of Yoshihara, deceleration would be effected for less than one-tenth of a second.

(3) ANALYSIS

(a) Claims 1 and 4

It is respectfully submitted that Yoshihara does not anticipate "gradually increasing a rate of . . . spinning," as recited in independent claim 1.

The acceleration and deceleration disclosed in Yoshihara are not gradual, as required by independent claim 1. Rather, as indicated in the tables of columns 9 and 10 of Yoshihara, the acceleration and deceleration between different spinning speeds are affected nearly instantaneously—at least 10,000 rpm/sec. When a substrate is rotated at speeds that vary from about 0 rpm to about 4,500 rpm, a 10,000 rpm/sec or greater (*e.g.,* 30,000 rpm/sec) acceleration or deceleration of the rotational speed of the substrate would not be gradual. For example, when the rate of spinning is decreased from 4,500 rpm to 2,000 rpm, at a rate of 30,000 rpm/sec, as disclosed at col. 9, lines 55-62, and col. 10, lines 8-10, deceleration would be effected for less than one-tenth of a second. This is about three times the deceleration in one-fiftieth to one-hundredth the amount of time as (*i.e.,* occurs about 150 times to about 300 times faster than) the deceleration between first and second speeds noted in the more gradual, nonlimiting example provided in paragraph **[0041]** of the above-referenced application.

It is, therefore, respectfully submitted that, under 35 U.S.C. § 102(b), independent claim 1 is allowable over Yoshihara.

Accordingly, reversal of the 35 U.S.C. § 102(b) rejections of independent claim 1 and claim 4 depending therefrom are respectfully requested.

(b) Claim 2

Claim 2 is allowable, among other reasons, for depending from claim 1, which is allowable.

Claim 2 is further allowable since Yoshihara lacks any express or inherent description that recesses in the substrate are substantially filled as the substrate is spun at a first speed. Instead, the disclosure of Yoshihara is limited to processes for reducing or eliminating the occurrence of ripples over the surface of a layer of material that has been applied to a substrate by spin coating processes.

Therefore, it is respectfully requested that the 35 U.S.C. § 102(a) rejection of claim 2 be reversed.

(c) Claim 3

Claim 3 is allowable, among other reasons, for depending from claim 1, which is allowable.

Claim 3 is additionally allowance since Yoshihara neither expressly nor inherently describes that, as a rate at which a substrate is spun is decreased to a second speed, material located within recesses of the substrate is permitted to set. Again, the description of Yoshihara is limited to spin coating processes which reduce or eliminate the occurrence of ripples on the surface of a material (*e.g.,* photoresist) layer.

For this reason, reversal of the 35 U.S.C. § 102(a) rejection of claim 3 is respectfully requested.

(C) REJECTIONS UNDER 35 U.S.C. § 103(a)

Claims 1-4, 7-11, 14-16, and 20-32 stand rejected under 35 U.S.C. § 103(a) as being unpatentable over the subject matter taught in Rodrigues.

(1) RELEVANT LAW

The standard for establishing and maintaining a rejection under 35 U.S.C. § 103(a) is set forth in M.P.E.P. § 706.02(j), which provides:

> To establish a *prima facie* case of obviousness, three basic criteria must be met. First, there must be some suggestion or motivation, either in the references themselves or in the knowledge generally available to one of ordinary skill in the art, to modify the reference or combine reference teachings. Second, there must be a reasonable expectation of success. Finally, the prior art reference (or references when combined) must teach or suggest all the claim limitations. The teaching or suggestion to make the claimed combination and the reasonable expectation of success must both be found in the prior art, and not based on applicant's disclosure. *In re Vaeck*, 947 F.2d 488, 20 USPQ2d 1438 (Fed. Cir. 1991).

(2) REFERENCE RELIED UPON

Rodrigues teaches a method which includes spinning a semiconductor wafer at a first speed, decreasing a rate at which the wafer is spun to a second speed, applying photoresist to the substrate while "concurrently decelerat[ing the rate of spinning the wafer] from the first rotational speed to [the] second rotational speed" (col. 2, line 65, to col. 3, line 5; col. 5, lines 22-47), then increasing the rate at which the wafer is spun to a third speed and further increasing the rate at which the wafer is spun to a fourth speed.

As Rodrigues teaches that photoresist is applied "at a very slow dispense rate" to a semiconductor wafer "during [constant] deceleration of the semiconductor wafer" from a first

speed to a second speed (col. 2, line 65, to col. 3, line 5; col. 4, lines 63-68), Rodrigues does not teach or suggest that material is applied to or located on the wafer as the wafer is spun at the first speed. Nor does Rodrigues teach or suggest maintaining the second rotational speed of the wafer once the material has been applied thereto and the second rotational speed has been reached.

(3) ANALYSIS

(a) Claims 1, 4, and 22

Independent claim 1 is directed to a spin coating method which includes applying a material to a substrate, spinning the substrate and the material at a substantially constant first speed, then decreasing a rate of spinning to a substantially constant second speed, followed by gradually increasing a rate of spinning to a substantially constant third speed.

It is respectfully submitted that Rodrigues does not support a *prima facie* case of obviousness against 1 because Rodrigues does not teach or suggest each and every element of any of claims 1-4, 7-11, 14-16, and 20-32.

The teachings of Rodrigues are limited to applying resist to a wafer "*during deceleration of the . . . wafer*" *from a first speed to a second speed.* Col. 2, line 65, to col. 3, line 5 (emphasis supplied); *see also* col. 5, lines 22-47. As noted at col. 4, lines 63-68, photoresist is applied "at a very slow dispense rate" as the rate of rotation of a semiconductor wafer "is *constantly* decelerating form a very high speed to a very slow speed" (emphasis supplied). Due to this combination of teachings, it is clear that photoresist is not dispensed at a "substantially constant first speed," as required by independent claim 1, but, rather, over an infinite plurality of constantly decreasing speeds. Thus, Rodrigues does not teach or suggest applying resist to a

substrate as it is spun at a "substantially constant first speed," as is required by independent claim 1.

Moreover, because Rodrigues teaches that the speed of a wafer is decreased as resist is applied thereto, then apparently immediately increased (as Rodrigues lacks any teaching or suggestion of maintaining the second speed), the rotational speed of the wafer is not "substantially constant" as the wafer is spun at the second speed of Rodrigues.

Even assuming, for the sake of argument, that the second speed of Rodrigues were considered to be analogous to the first speed of independent claim 1, the subsequent third speed of Rodrigues is greater than the second speed. Col. 6, lines 13-17. Therefore, when such an assumption is made, the teachings of Rodrigues are opposite to the requirements of independent claim 1; *i.e.,* in Rodrigues, an increase in rotational speed occurs from one speed (*i.e.,* the second speed of Rodrigues) to the next speed (*i.e.,* the third speed of Rodrigues), whereas independent claim 1 requires a decrease from the first speed to the second speed.

Thus, Rodrigues cannot teach or suggest both spinning a substrate with a material thereon at a first speed and the sequence of spinning, decreasing, then increasing the rotational speed of the substrate that are recited in independent claim 1.

Claims 4 and 22 are both allowable, among other reasons, for depending directly and indirectly, respectively, from claim 1, which is allowable.

For these reasons, reversal of the 35 U.S.C. § 103(a) rejections of claims 1, 4, and 22 is respectfully requested.

(b) Claim 2

Claim 2 is allowable, among other reasons, for depending from claim 1, which is allowable.

Claim 2, which recites that material may substantially fill recesses of a substrate as the substrate is spun at a substantially constant first speed, is additionally allowable since Rodrigues neither teaches nor suggests that resist is present on the wafer as the wafer is being spun at the first speed. This is because the teachings of Rodrigues are limited to the application of resist to the wafer *after* the wafer has been rotated at the first speed thereof. Col. 2, line 65, to col. 3, line 5; col. 5, lines 22-27.

Again, if the second speed of Rodrigues is considered to be analogous to the first speed of independent claim 1, the teachings of Rodrigues with respect to order in which the rotational speed of a wafer is increased and decreased are inconsistent with that recited in independent claim 1. Col. 6, lines 13-17. Thus, when such an assumption is made, there is no need to address the issue of whether or not recesses in the wafer would be filled with resist as the wafer is spun at the second speed taught in Rodrigues.

If it is assumed that the first speed of claim 2 occurs at some instant, frozen in time, between the continual deceleration from the first rotational speed of Rodrigues to the second rotational speed thereof, there could be no flow of material into a recess, as required by claim 2, at an instant that is frozen in time.

Therefore, it is respectfully requested that the 35 U.S.C. § 103(a) rejection of claim 2 be reversed.

(c) Claim 3

Claim 3 is allowable for depending from claim 1 and, additionally, because Rodrigues lacks any teaching or suggestion that, as the rotational speed of a wafer is decreased from a first speed to a second speed, resist within recesses of the wafer may substantially set. To restate: according to the teachings of Rodrigues, there is never resist on the wafer as the wafer is rotated at a first speed. Col. 2, line 65, to col. 3, line 5; col. 5, lines 22-27.

Even if it is assumed that the second rotational speed of Rodrigues is analogous to the first speed recited in independent claim 1, it is respectfully submitted that, by teaching that, as soon as the wafer reaches the second rotational speed, dispensing of resist ceases and the spinning of the wafer is accelerated to a third rotational speed (*see, e.g.,* col. 3, lines 2-10; col. 5, lines 44-46, and col. 6, lines 13-17; Rodrigues teaches the duration at which the rotation is held at the third rotational speed thereof, but includes no such teaching for either the first or second rotational speeds thereof), there would not be time for the resist to set *during* the second rotational speed.

For this reason, reversal of the 35 U.S.C. § 102(a) rejection of claim 3 is respectfully requested.

(d) Claim 21

Claim 21 is allowable for depending from claim 1.

Claim 21 is further allowable since Rodrigues does not teach or suggest *decreasing* a rate of spinning of a substrate to a fourth speed after the rate of spinning of the substrate was increased to a third speed. Rather, the teachings of Rodrigues are limited to increasing the rate of

spinning of a wafer from a second speed to a third speed (col. 6, lines 13-17), then further *increasing* the rate at which the wafer is spun to a fourth speed (col. 6, lines 48-54).

Accordingly, it is respectfully requested that the 35 U.S.C. § 103(a) rejection of claim 21 be reversed.

(e) Claim 23

Claim 23 is allowable for depending from claims 21 and 1, which are allowable.

Claim 23, which depends from claim 21, is also allowable because Rodrigues lacks any teaching or suggest that, following decreasing of the rotational speed of a substrate to a fourth speed, the rotational speed of the substrate may again be increased to a fifth speed.

It is, therefore, respectfully requested that the 35 U.S.C. § 103(a) rejection of claim 21 be reversed.

(f) Claims 7, 8, 11, 26, and 28

Independent claim 7 recites a spin coating method which includes applying a material to a substrate, spinning the substrate and the material at a first speed that permits the material to flow into recesses formed in the substrate, then spinning the substrate at a second speed that permits material within the recesses to set, and, thereafter, gradually increasing a rate at which the substrate is spun to a third speed.

Rodrigues neither teaches nor suggests spinning a substrate and material thereon at a first speed that permits the material to flow into recesses formed in the substrate. Instead, Rodrigues teaches a method which includes *very slowly applying* resist to a wafer *after* the wafer has been

spun at a first rotational speed, as the rate of rotation is being *constantly decelerated* from the first rotational speed to a second rotational speed. Col. 4, lines 63-68.

As there is no material on the wafer at a first speed, material could not flow into recesses formed in the wafer as the wafer is being spun at a first speed.

If it is assumed that the first speed of independent claim 7 occurs at some instant, frozen in time, between the continual deceleration from the first rotational speed of Rodrigues to the second rotational speed thereof, there could be no flow of material into a recess, as required by independent claim 7, at an instant that is frozen in time.

Again assuming, for the sake of argument, that the second speed of Rodrigues corresponds to the first speed recited in independent claim 7, resist could not flow into recesses of the wafer at the second speed because rotation of the wafer is merely decelerated to the second speed, then apparently immediately increased to a third speed.

Accordingly, Rodrigues does not teach or suggest each and every element of independent claim 7. It is, therefore, respectfully submitted that, under 35 U.S.C. § 103(a), independent claim 7 recites subject matter which is allowable over the teachings of Rodrigues.

Each of claims 8, 11, 26, and 28 is allowable, among other reasons, for depending either directly or indirectly from claim 7, which is allowable.

Therefore, it is respectfully requested that the 35 U.S.C. § 103(a) rejections of claims 7, 8, 11, 26, and 28 be reversed.

(g) Claim 9

Claim 9 is allowable for depending from claim 7 and, further, because Rodrigues cannot teach or suggest both that material is applied to a substrate which is spun at a first speed and that, thereafter, the rate at which the substrate spun is decreased. If it is the first speed of Rodrigues that corresponds to the first speed of independent claim 7, in the method of Rodrigues, resist has not yet been applied to the wafer (col. 2, line 65, to col. 3, line 5; col. 5, lines 22-27), as required by independent claim 7. If, in the alternative, it is the second speed of Rodrigues that corresponds to the first speed of independent claim 7, Rodrigues teaches that the rotational speed of the wafer is *increased* to a third speed (col. 6, lines 13-17), not *gradually decreased* to a second speed, as required by claim 9.

For this reason, reversal of the 35 U.S.C. § 103(a) rejection of claim 9 is respectfully requested.

(h) Claim 10

Claim 10, which recites that material may substantially fill recesses of a substrate as the substrate is spun at a first speed, is additionally allowable since Rodrigues neither teaches nor suggests that, as the wafer is being spun at the first or second speed thereof, resist may flow into recesses that are formed in the wafer. With respect to the first speed of Rodrigues, there is not yet any resist on the wafer with which recesses therein may be substantially filled. Col. 2, line 65, to col. 3, line 5; col. 5, lines 22-27. As for the second speed of Rodrigues, at which resist is present on the wafer, Rodrigues lacks any teaching or suggest that the second speed is

maintained for any period of time, let alone for a sufficient duration to permit resist to substantially fill recesses formed in the wafer.

Therefore, it is respectfully requested that the 35 U.S.C. § 103(a) rejection of claim 10 be reversed.

(i) Claim 25

Claim 25 is further allowable since Rodrigues does not teach or suggest decreasing a rate of spinning of a substrate to a fourth speed after the rate of spinning of the substrate was increased to a third speed. Rather, the teachings of Rodrigues are limited to increasing the rate of spinning of a wafer from a second speed to a third speed (col. 6, lines 13-17), then further increasing the rate at which the wafer is spun to a fourth speed (col. 6, lines 48-54).

Reversal of the 35 U.S.C. § 103(a) rejection of claim 25 is, therefore, respectfully requested.

(j) Claim 27

In addition to being allowable for depending from claims 7 and 25, claim 27 is allowable because Rodrigues lacks any teaching or suggest that, following decreasing of the rotational speed of a substrate to a fourth speed, the rotational speed of the substrate may again be increased to a fifth speed.

Accordingly, it is respectfully requested that the 35 U.S.C. § 103(a) rejection of claim 21 be reversed.

(k) Claims 14, 20, 30, and 32

Independent claim 14 is drawn to a spin coating method that includes applying a material to a substrate, spinning the substrate at a first speed to at least partially spread the material, then spinning the substrate at a second speed to permit at least some of the material to flow into at least on recess formed in the substrate, and, thereafter, gradually increasing a rate of spinning of the substrate to a third speed.

Rodrigues does not teach or suggest spinning a substrate and at a first speed to at least partially spread material thereon. Rather, the teachings of Rodrigues are limited to a method which includes *very slowly applying* resist to a wafer as it is being *constantly decelerated* from a first speed, at which resist was not present on the wafer, to a second speed.

If it is assumed that the first speed of independent claim 14 occurs at some instant, frozen in time, between the continual deceleration from the first rotational speed of Rodrigues to the second rotational speed thereof, there could be no spreading of material, as required by independent claim 14, at an instant that is frozen in time.

Assuming again, *arguendo,* that the second speed of Rodrigues corresponds to the first speed recited in independent claim 14, neither Rodrigues nor the knowledge that is generally available in the art provides any teaching or suggestion that increasing the rate of spinning to the third speed thereof, which corresponds to the second speed of independent claim 14, would permit at least some material to flow into recesses formed in the wafer thereof.

Therefore, Rodrigues does not teach or suggest each and every element of independent claim 14, as would be required to uphold the 35 U.S.C. § 103(a) rejection of independent claim 14.

Claims 20, 30, and 32 are each allowable, among other reasons, for depending directly or indirectly from claim 14, which is allowable.

In view of the foregoing, it is respectfully requested that the 35 U.S.C. § 103(a) rejections of claims 14, 20, 30, and 32 be reversed.

(l) Claim 15

Claim 15 is allowable, among other reasons, for depending from claim 14, which is allowable.

Claim 15, which recites that material may substantially fill recesses of a substrate as the substrate is spun at a first speed, is additionally allowable since Rodrigues neither teaches nor suggests that, as the wafer is being spun at the first or second speed thereof, resist may flow into recesses that are formed in the wafer. With respect to the first speed of Rodrigues, there is not yet any resist on the wafer with which recesses therein may be substantially filled. Col. 5, lines 22-27. As for the second speed of Rodrigues, at which resist has been applied to the wafer, Rodrigues lacks any teaching or suggest that the second speed is maintained for any period of time, let alone for a sufficient duration to permit resist to substantially fill recesses formed in the wafer.

It is, therefore, respectfully requested that the 35 U.S.C. § 103(a) rejection of claim 15 be withdrawn.

(m) Claim 16

Claim 16 is allowable for depending from claim 14 and, further, because Rodrigues cannot teach or suggest both that material is applied to a substrate which is spun at a first speed and, thereafter, the rate at which the substrate spun is decreased. If it is the first speed of Rodrigues that corresponds to the first speed of independent claim 14, in the method of Rodrigues, resist has not yet been applied to the wafer (col. 5, lines 22-27), as required by independent claim 14. If, in the alternative, it is the second speed of Rodrigues that corresponds to the first speed of independent claim 14, Rodrigues teaches that the rotational speed of the wafer is *increased* to a third speed (col. 6, lines 13-17), not *gradually decreased* to a second speed, as required by claim 16.

Accordingly, reversal of the 35 U.S.C. § 103(a) rejection of claim 16 is respectfully requested.

(n) Claim 29

Claim 29 is allowable, among other reasons, for depending from claim 14, which is allowable.

Claim 29 is further allowable since Rodrigues does not teach or suggest decreasing a rate of spinning of a substrate to a fourth speed after the rate of spinning of the substrate was increased to a third speed. Rather, the teachings of Rodrigues are limited to increasing the rate of spinning of a wafer from a second speed to a third speed (col. 6, lines 13-17), then further increasing the rate at which the wafer is spun to a fourth speed (col. 6, lines 48-54).

Reversal of the 35 U.S.C. § 103(a) rejection of claim 29 is, therefore, respectfully requested.

(o) Claim 31

Claim 31, which is allowable for depending from claims 14 and 29, is also allowable because Rodrigues lacks any teaching or suggest that, following decreasing of the rotational speed of a substrate to a fourth speed, the rotational speed of the substrate may again be increased to a fifth speed.

Therefore, it is respectfully requested that the 35 U.S.C. § 103(a) rejection of claim 31 be reversed.

(9) APPENDICES

A copy of Wolf is enclosed herewith as Appendix A as evidence that one of ordinary skill in the art would readily understanding the meaning of the term "gradually," as used in the claims of the above-referenced application to describe the rotational acceleration or deceleration of a substrate.

The status of each claim that has been introduced in the above-referenced application is reproduced in Appendix B.

(10) CONCLUSION

It is respectfully submitted that:

(A) Each of claims 1, 7, and 14 recites subject matter which complies with the definiteness requirement of 35 U.S.C. § 112, second paragraph;

(B) Each of claims 1-4 is allowable under 35 U.S.C. § 102(a) because Yoshihara does not anticipate the subject matter recited therein; and

(C) Claims 1-4, 7-11, 14-16, and 20-32 are allowable under 35 U.S.C. § 103(a) for being directed to subject matter which is patentable over the teachings of Rodrigues.

Accordingly, it is respectfully requested that the rejections of claims 1-4, 7-11, 14-16, and 20-32 be reversed and that each of these claims be allowed.

Respectfully submitted,

Brick G. Power
Registration No. 38,581
Attorney for Applicants
TRASKBRITT, PC
P.O. Box 2550
Salt Lake City, Utah 84110-2550
Telephone: 801-532-1922

Date: August 18, 2004

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APPENDIX B

CLAIMS

1. (Previously presented) A spin coating method, comprising:

applying a material to a substrate;

spinning the substrate and the material at a substantially constant first speed;

following the spinning, decreasing a rate of spinning to a substantially constant second speed; and

following decreasing, gradually increasing a rate of the spinning to a substantially constant third speed.

2. (Previously presented) The method of claim 1, wherein spinning the substrate and the material at the first speed comprises substantially filling recesses formed in the substrate with the material.

3. (Previously presented) The method of claim 1, wherein decreasing the rate of spinning to the second speed comprises permitting material located within recesses formed in the substrate to set.

4. (Previously presented) The method of claim 1, further comprising:

spinning the substrate and the material at the third speed to form a layer comprising the material over a surface of the substrate to a desired thickness.

5-6. (canceled)

7. (Previously presented) A spin coating method, comprising:

applying a material to a substrate;

spinning the substrate and the material at a first speed that permits the material to flow into recesses formed in the substrate;

spinning the substrate at a second speed that permits the material within the recesses to set; and

following spinning the substrate at the second speed, gradually increasing a rate of spinning of the substrate to a third speed.

8. (Previously presented) The method of claim 7, wherein spinning the substrate at the second speed follows spinning the substrate at the first speed.

9. (Previously presented) The method of claim 8, wherein spinning the substrate at the second speed comprises decreasing a rate at which the substrate is spun.

10. (Previously presented) The method of claim 7, wherein spinning the substrate and the material at the first speed comprises substantially filling the recesses with the material.

11. (Previously presented) The method of claim 7, further comprising:

spinning the substrate and the material at the third speed comprises to form a layer comprising the material over a surface of the substrate to a desired thickness.

12-13. (canceled)

14. (Previously presented) A spin coating method, comprising:

applying a material to a substrate;

spinning the substrate at a first speed to at least partially spread the material;

following spinning the substrate at the first speed, spinning the substrate at a second speed to permit at least some of the material to flow into at least one recess formed in the substrate; and

following spinning the substrate at the second speed, gradually increasing a rate of spinning of the substrate to a third speed.

15. (Previously presented) The method of claim 14, wherein spinning the substrate at the first speed comprises substantially filling the at least one recess with the material.

16. (Previously presented) The method of claim 14, wherein spinning the substrate at the second speed comprises spinning the substrate at a speed that is slower than the first speed.

17-19. (canceled)

20. (Previously presented) The method of claim 14, further comprising:
spinning the substrate at the third speed to form a layer comprising the material over a surface of the substrate to a desired thickness.

21. (Previously presented) The method of claim 1, further comprising:
following gradually increasing, again decreasing a rate of spinning of the substrate to a fourth speed.

22. (Previously presented) The method of claim 21, comprising permitting the material to set further while spinning the substrate at the fourth speed.

23. (Previously presented) The method of claim 21, further comprising:
following the again decreasing, again increasing a rate of spinning of the substrate to a fifth speed.

24. (Previously presented) The method of claim 23, comprising substantially removing solvent from the material while spinning the substrate at the fifth speed.

25. (Previously presented) The method of claim 7, further comprising:
following gradually increasing, again decreasing a rate of spinning of the substrate to a fourth speed.

26. (Previously presented) The method of claim 25, comprising permitting the material to set further while spinning the substrate at the fourth speed.

27. (Previously presented) The method of claim 25, further comprising:
following the again decreasing, again increasing a rate of spinning of the substrate to a fifth speed.

28. (Previously presented) The method of claim 27, comprising substantially removing solvent from the material while spinning the substrate at the fifth speed.

29. (Previously presented) The method of claim 14, further comprising:
following gradually increasing, again decreasing a rate of spinning of the substrate to a fourth speed.

30. (Previously presented) The method of claim 29, comprising permitting the material to set further while spinning the substrate at the fourth speed.

31. (Previously presented) The method of claim 29, further comprising:
following again decreasing, again increasing a rate of spinning of the substrate to a fifth speed.

32. (Previously presented) The method of claim 31, comprising substantially removing solvent from the material while spinning the substrate at the fifth speed.

SILICON PROCESSING FOR THE VLSI ERA

VOLUME 1:

PROCESS TECHNOLOGY

STANLEY WOLF Ph.D.
Professor, Department of Electrical Engineering
California State University, Long Beach
Long Beach, California
and
Instructor, Engineering Extension, University of California, Irvine

RICHARD N. TAUBER Ph.D.
Manager of VLSI Fabrication
TRW - Microelectronics Center
Redondo Beach, California
and
Instructor, Engineering Extension, University of California, Irvine

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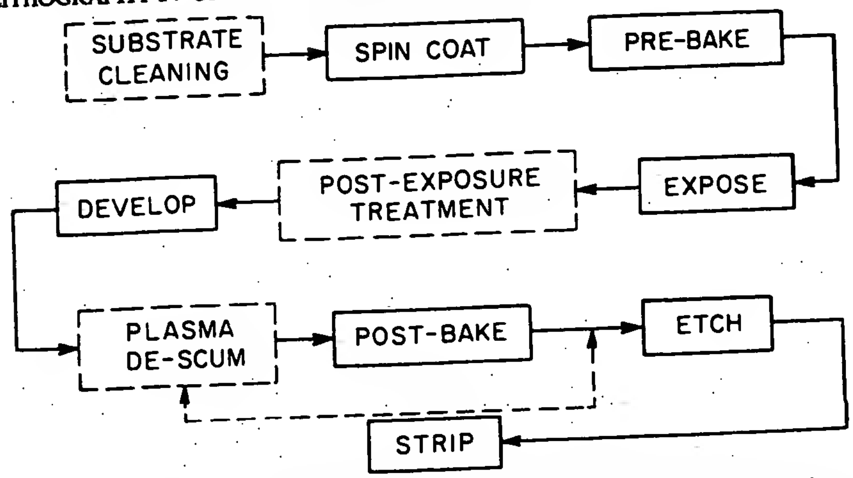

Fig. 14 Flow chart of a typical resist process. Steps in broken lines are not used for all materials. Reprinted from Ref. 8 with permission of the American Chemical Society.

One of the major limitations of photosensitive polyimide material has been their short shelf-life stability. Research to improve this shortcoming, however, is being actively pursued, with apparently successful promise[30].

PHOTORESIST PROCESSING

The basic sequence of steps that comprise a complete photoresist process is shown in Fig. 14. The remaining sections of this chapter describe these steps in detail. There are a few steps that are covered in other chapters, including *Wafer Cleaning* (Chap. 15), *Etching* (Chaps. 15 and 16), and *Photoresist Stripping* (Chap. 15).

It will be seen that the steps of a complete resist process are not independent of one another. That is, in specifying one step, several other steps will be impacted. As a result, the development of a resist process requires substantial effort. Many facets of the process development are largely empirical, and thus, as much (if not more) art as science, is performed in establishing an effective resist process.

Resist Processing: Dehydration Baking and Priming

Many resist processing problems can be attributed to dirty or contaminated surfaces. Thus, it is important that a substrate be clean in order not to adversely affect the lithographic process. Some common problems traced to dirty surfaces include poor adhesion and defects (such as pinholes and opaque spots). Loss of linewidth control, and in extreme cases, the entire loss of pattern elements, can result from poor adhesion. Since most surfaces in VLSI fabrication are formed either by thermal oxidation or by reduced pressure deposition techniques, *in most cases the surface is in its cleanest form immediately after having been formed*. Thus, further cleaning can be avoided by *coating the surface as quickly as possible with resist after deposition*. Wafer cleaning techniques in some cases may be necessary, and are discussed in Chap. 15.

Moisture from the atmosphere can be rapidly absorbed by substrate surfaces, and such hydrated surfaces have been shown to reduce adhesion. Therefore, a *dehydration bake step* is often

performed before priming and spin-coating a wafer with resist. When carried out at atmospheric pressure, dehydration baking evolves moisture at three temperature plateaus[32]: a) surface water molecules are liberated at 150-200°C; b) loosely held water of hydration is evolved at about 400°C; and c) total dehydration has been postulated to occur at temperatures in excess of 750°C. It is believed, however, that upon cooling, the water of hydration removed in step c) is reabsorbed from atmospheric moisture. Thus, some reports argue that no significant improvement over baking at 400°C should be expected. What is apparently important is the time delay between the dehydration bake and coating. In fact, to assure uniformity of processing, the recommended procedure is to carry out coating immediately after the dehydration bake. Dehydration bakes of up to 400°C are generally carried out in convection ovens, while 800°C bakes are performed in furnace tubes (both, of course, in dry-gas ambients).

Following the dehydration bake, the wafer is normally *primed* with a pre-resist coating of a material designed to improve adhesion even further[33]. The most widely used priming substance is hexamethyldisilazane (HMDS)[34]. Figure 15 shows how one end of the HMDS molecule reacts with wafer-oxide surfaces to tie up molecular water on a hydroxilated SiO_2 surface. It also shows how the other end of the HMDS molecule forms a bond with the *resist*. Thus, it is seen that the HMDS behaves as surface-linking *adhesion promoter* (e.g. SiO_2 surface-to-resist surface linkage). The wafers should be coated with resist as quickly as possible after priming, and it is recommended that coating be performed no later than 60 min after completing the priming step.

The HMDS is typically applied to the surface in one of two methods: a) spin coating; and b) vapor priming. In *spin coating*, the HMDS is dispensed onto the wafer surface through an additional nozzle present in the resist spin coating system. After the HMDS is dispensed, the wafer is spun at 3000-6000 rpm for 20-30 sec, causing approximately a monolayer of HMDS to remain on the wafer surface. In *vapor priming*, the HMDS is introduced in vapor form into a chamber containing the wafers. An exposure of the wafer surfaces to the HMDS vapor for ~10 min primes the surface so that good adhesion is obtained. The advantages of vapor priming are the following: a) wafers can be batch primed; b) since only vapors come in contact with the wafer surface, potential contamination from particles present in the HMDS solution is avoided; and c) less HMDS is used per wafer, thus providing a cost savings. Equipment that combines a vacuum dehydration bake of the wafers in the same chamber, prior to introducing HMDS vapors, is also commercially available. Such systems offer the opportunity to prime the wafers after vacuum dehydration baking (i.e. at a temperature less than is required for an atmospheric pressure bake), and without subsequently having to expose the wafers to atmospheric moisture.

Resist Processing: Coating

Following cleaning, dehydration baking, and priming, the wafers are ready to be coated with photoresist. The goal of the coating step is to produce a uniform, adherent, defect-free polymeric

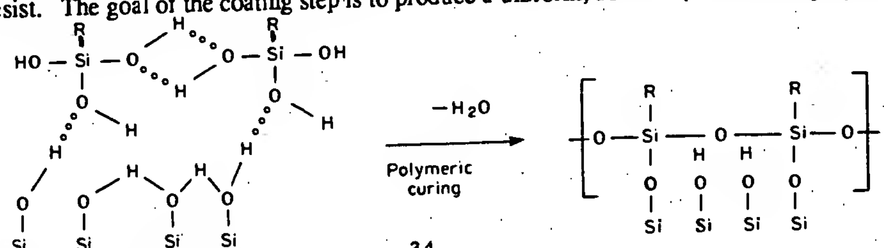

Fig. 15 HMDS bonding mechanism with SiO_2[34].

film of desired thickness over the entire wafer. *Spin coating* is by far the most widely used technique to apply such films[35,36]. This procedure is carried out by dispensing the resist solution onto the wafer surface, and then rapidly spinning the wafer until the resist is essentially dry. In order to maintain reproducible linewidth in VLSI fabrication applications, resist film uniformity across the wafer (and from wafer-to-wafer) should be within at least ±100Å.

The spin coating procedure involves three stages: a) dispensing the resist solution onto the wafer; b) accelerating the wafer to the final rotational speed; and c) spinning at a constant speed to establish the desired thickness (and to dry the film).

The *dispensing stage (a)* can either be accomplished by flooding the entire wafer with resist solution before beginning the spinning, or by dispensing a smaller volume of resist solution at the center of the wafer and spinning at low speeds (e.g. 200 rpm for ~1 sec) to produce a uniform liquid layer across the wafer (*spread cycle*). In the latter method ~3.0 ml of resist is dispensed onto 100 mm wafers, and ~5.0 ml onto 150 mm wafers. It has also been found that *static dispense* (in which the wafer is stationary as the resist is dispensed), provides more uniform coatings than if the wafer is rotating (*dynamic dispense*).

In *Stage (b)* the wafers are normally *accelerated* as quickly as is practical to the final spin speed. High ramping rates have been shown to yield better film uniformities than low ramping rates. This is due to the fact that the solvent in the resist evaporates rapidly from the resist after it has been dispensed onto the wafer. Since film thickness depends on the viscosity of the liquid resist solution, the more time that is allowed for the solvent to evaporate during the spin-ramping to the final speed, the greater are the drying and film setting-up tendencies that contribute to thickness non-uniformity. A spin-ramp of 20,000 rpm /sec has been suggested as an adequate compromise to provide maximum coating uniformity, without causing motor-wear problems or excessive wafer breakage.

During *Stage (c)* the resist layer acquires a relatively uniform, symmetrical flow profile

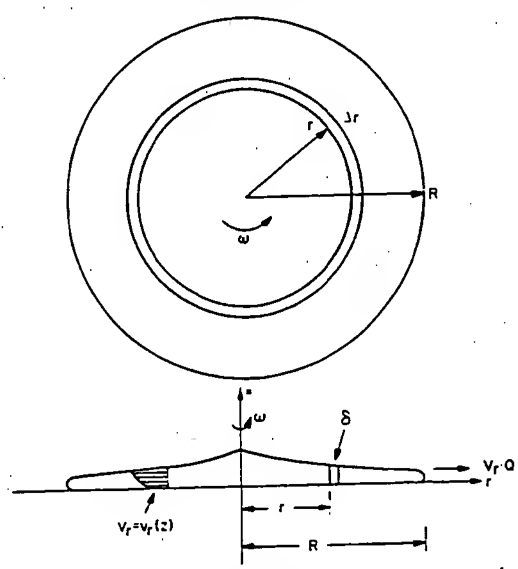

Fig. 16 Symmetrical flow pattern of a homgeneous liquid on a rotating disk showing flow rate, Q, and velocity profile v_r (z). Copyright 1977 by International Business Machines Corporation; reprinted with permission.

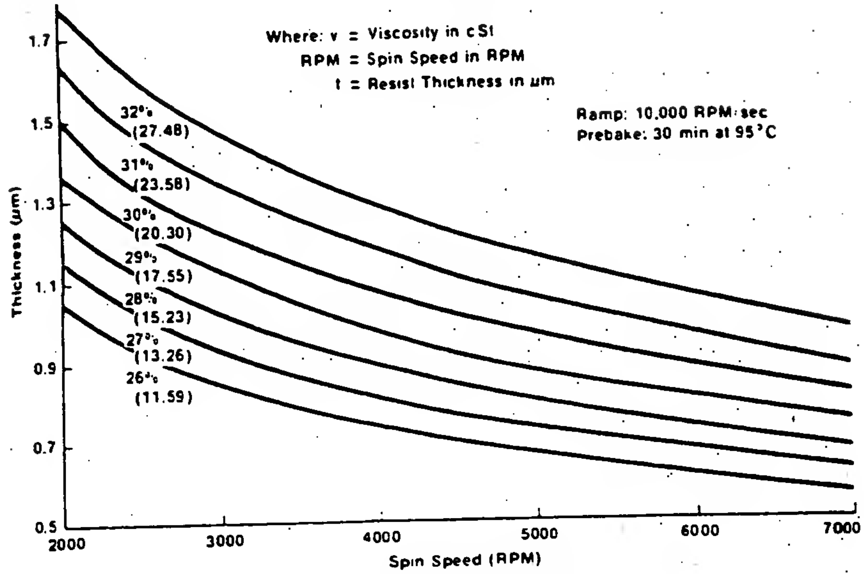

Fig. 17 Thickness vs spin speed of Kodak 820 resist. Courtesy of Eastman-Kodak Company.

(as shown in Fig. 16). Once this structure has been formed, the remainder of the high speed spinning cycle consists of solvent evaporation to produce the solid film. Most spin coating processes are performed with a final spin speed in the 3000-7000 rpm range for 20-30 sec, as this range provides good film uniformity, as well as limited spin-motor wear and wafer breakage. The highest degree of thickness uniformity (±100Å) is observed at the upper end of the range (6000-7000 rpm).

The spin coating fluid dynamics have been studied in some detail[35]. It has been determined that prior to reaching the "equilibrium" form of Fig. 16[42], the resist layer undergoes some intermediate shapes. At the start of spinning (i.e. within a few hundredths of a second), a wave of resist is created that then moves toward the wafer edge. The *corona stage* is next observed, in which the bulk of the resist that supported the wave runs out to the wafer edge to form a crown-like structure. When most of the resist has been driven off the wafer, the wave and corona disappear. At that point, centrifugal forces drive the remaining resist material off the surface in a fine spray that exhibts a spiral-like appearance. This *spiral stage* generates thousands of resist droplets as the material reaches the wafer edge and is flung off. The droplets leave the wafer at high speed and are thus subject to being bounced off of the spinner bowl sides, and redeposited on the wafer surface. To avoid this possibility, plastic splashguards and special exhausted bowl designs have been developed. An *edge bead* (a remnant of the corona stage, several times as thick as the deposited resist layer), also develops along the wafer edge during the spinning process[39]. Edge-rounding of the wafers significantly reduces the edge-bead, and wafer backside washing with solvent after spin-coating can entirely remove it (as described further in Chap. 15).

The resist film thickness after spin coating, for a resist of constant molecular weight, solution concentration, etc., depends only on the spinning parameters. As an example, Fig. 17 shows the thickness curves of Kodak Micro Positive Resist 820 as a function of spin speed. Various mathematical relationships have been developed to predict the resist thickness as it depends upon such factors as percent solids, spin speed, etc. Most users, however, utilize data from the resist manufacturer to plan a baseline spin-coating process, and then empirically

generate spin speed curves for their own specific process applications (i.e. that will depend on such specific parameters as resist formulation, spinner type, wafer size, spin parameters, and ambient temperature during deposition)[40]. A study of thickness variation across a wafer as a function of many such parameters, including volume of resist dispensed, wafer diameter, resist viscosity, wafer spin-speed during dispense, wafer acceleration, and final spin-speed, was published in Refs. 37 and 38.

Resist film thickness can be measured in many ways. *Contacting types* of thickness measuring instruments are *surface profilometers*, which are capable of resolving 200Å steps. These are described in more detail in Chap 10. *Noncontact types* of thickness instruments utilize optical techniques of ellipsometry or interferometry. Automatic interferometer-based instruments have become widely used for resist thickness measurement, since they are easy to use, accurate, and perform the measurement quickly. Such instruments are discussed in Chap. 8.

There are also a variety of other aspects of the coating procedure that must be controlled in order to maintain an effective coating process, including: a) defect generation; b) the environment in which the coating is performed; and c) wafer handling and storage.

Defects can be introduced during the coating process in a number of ways, and some steps to minimize their generation include the following: a) Since the resist film is sticky until being soft-baked, it can easily entrap airborne particles. Thus, spinning should be done in a Class-100, or better, environment; b) The resist itself should be clean and free of all particulate matter above 0.2 µm in diameter. (Resist cleanliness and filtration prior to use is considered in an earlier section of this chapter.); c) The resist solution should be free of all entrapped air, as air bubbles can cause defects in the resist image that have the same effect as those caused by particles. Allowing a resist to sit for several days after filtration, and prior to application, will let dissolved air and gases to escape; d) radial resist striations (i.e. radial streaks of thickness different than the nominal resist thickness) are a form of defect caused by non-uniform solvent evaporation. One cause of striations has been attributed to excessive venting of the spin bowl[35]. This depletes the solvent content from the ambient around a spinning wafer, and apparently leads to striation formation. Spin bowl exhaust flow can be controlled by special flow meters designed to sense the flow of gases in the bowl exhaust lines. When multiple bowls are exhausted by a single pump, the exhaust flow in a single line can vary if it is not controlled. This can cause resist thickness nonuniformities[83]; e) the spin bowl should be designed to prevent splashback by resist droplets being spun off of the wafers; f) the nozzle that dispenses resist onto the wafer should be set close to the wafer surface to prevent splashing effects; g) the pump that controls the resist being dispensed through the nozzle should be designed to provide a *suck-back* action after the resist volume is dispensed onto the wafer. This suck-back function draws excess resist from the nozzle tip back into the supply line, thus preventing unwanted dripping onto the spinning wafer. The suck-back stroke must be adjustable so that air is not inadvertently drawn up into the nozzle tip. This could cause bubbles to become entrapped in the resist present in the nozzle line; and h) the chuck should be properly designed. That is, the chuck diameter should be large enough to consistently hold wafers and prevent breakage, and the vacuum ports should fasten wafers to the chuck in such a fashion that does not cause a resist puddle to form at the center of the wafer (due to *dishing*). Multiple vacuum ports are therefore preferred, as they distribute the vacuum force across the wafer area. (Note that new wafer hold-down mechanisms may need to be developed as wafer diameters and thicknesses continue to increase.)

The *environment in which the spin-coating is carried out*, must also be controlled. Since resist viscosity, and hence film thickness, depends on temperature, the latter should be controlled to ±1°C. In addition, the wafers, resist, and spinner hardware all need to maintained in thermal

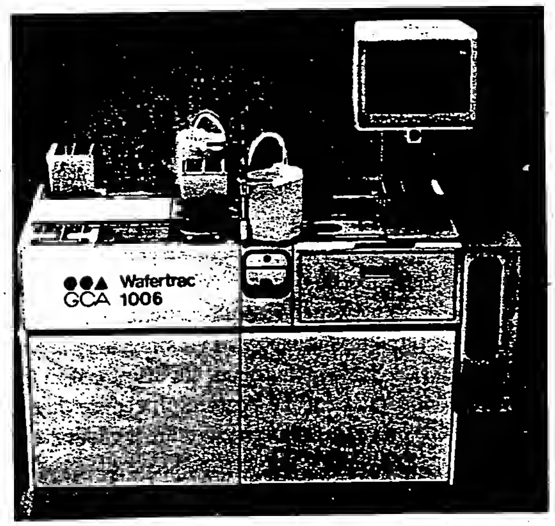

Fig. 18 Photograph of an automated in-line wafer spin coater. Courtesy of the GCA Corp.

equilibrium with one another. During spinning, solvent evaporation can lead to wafer cooling, and this may cause condensation of moisture on the resist surface. To avoid this problem, it has been recommended that the humidity be maintained at less than 50% RH. Since solvent vapors are flammable, exhaust equipment should also be spark-resistant to prevent the possibility of fire.

Upon completing the spin-coating cycle, wafers should be transported to the next step of the process, namely soft-bake, as soon as possible. Unbaked freshly spun films should not be stored in excess of a few hours, since their tacky consistency makes them vulnerable to particulate contamination. If particles contact the resist surface prior to soft-bake they become almost impossible to remove, and they will lead to pinhole or opaque defects after exposure and development. The wafers should be placed in a dry box for short-term storage, and should be soft-baked immediately before exposure.

Resist coating equipment (e.g. Fig. 18) is manufactured by a variety of suppliers[41]. Most suppliers offer equipment with cassette-to-cassette operation. Wafer handling and transport systems vary from one model to another. Microprocessor control, including programming capability, and a *lock-out* feature, is also typically offered (i.e. in lock-out, once the coating process recipe has been programmed into the machine, it cannot be altered unless the system is "unlocked", presumably by a responsible authority). Equipment process control and diagnostic capabilities are also offered. Since more than one wafer size may need to be processed, the ability to handle multiple wafer sizes may be important. Equipment that can perform priming, baking, and coating on one track in an automated manner, is also coming into widespread use.

Resist Processing: Soft-Bake

After wafers are coated with resist, they are subjected to a temperature step, called ***soft-bake*** (or *pre-bake*)[42,43]. This step accomplishes several important purposes, including: a) driving off solvent from the spun-on resist, reducing its level in the film from ~20-30% to ~4-7%; b) improving the adhesion of the resist, so that it is better able to adhere during the development step; and c) annealing the stresses caused by the shear forces encountered in the spinning process.